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THE INCLUSIONS IN THE GRANITE OF CRAFTSBURY, VT.

BY CALVIN McCORMICK.

The inclusions usually found in granites are observed to vary to a marked extent in outline, structure and mode of occurrence. Very often they resemble imbedded fragments of older rocks. They are usually darker than the including granite, and are either circular or angular. When rounded they resemble an enclosed pebble; when angular, a fragment of slate or mica schist. They sometimes merge into the surrounding rock by thrusting out minute connective particles. They are generally finer in texture, and hence less easily decomposed by atmospheric agencies than the enclosing granite.

A reference to the recorded observations on granitic inclusions will doubtless assist materially in the study of the subject. In 1821, Dr. John Macculloch, in his " Geological Classification of Rocks," p. 230, refers to inclusions as "irregular patches or veins of a fine texture, spheroidal in arrangement, imbedded in coarse granite." In 1858, Dr. Carl F. Naumann refers to " pseudo-fragmentary concretions resembling sharp-angled fragments common in crystalline siliceous rocks." (Lehrbuch der Geognosie, 2 Auf., Band I, S. 422, 560; B. II, S. 203.)

In the same year Dr. F. Hochstetter states that " the granites of Billston Island contain micaceous fine-grained, dark, globular enclosures." (Jahrb. k. k. geolog. Reichsan., S. 285.)

In 1863, Dr. F. V. Andrian, referring to the hornblendic granites of Central Bohemia, mentions " innumerable fine-grained enclosures, sharply segregated from the surrounding rock, varying in size from $\frac{1}{20}$ to 4 inches in diameter. These enclosures contain small quantities of hornblende crystals. From their abundance and identity of constituents they were produced during the solidification of the rock mass, by a process of segregation, the exact nature of which is unknown." (Beit. z. Geolog. d. Kaur. Tab. Krei. Böhmen, S. 166.)

In an article on the " Metamorphic Origin of certain Granitoid Rocks and Granites in the Southern Uplands of Scotland," Prof. James Geikie describes " nests of altered rock in a gray granite. These are distinctly laminated, fine-grained, micaceous and imparting a dark shade to the rock. They are irregular in shape, and scattered indiscriminately throughout the mass." (Geological Magazine, 1861, vol. 3, p. 533.)

All of these observations relate to the external appearance of these inclusions. No one of these writers has given us an intimation of the microscopic or chemical nature of their internal structure. In this respect Prof. J. A. Phillips has greatly surpassed his predecessors.

In the Quarterly Journal of the Geological Society, vol. 36, p. 1, this author describes granites and their inclusions from numerous British localities. The Cornwall granites at Lamorna, Zennor, and Luxulyan contain numerous black patches, angular, fine-grained and composed of quartz and mica. The granite of Shap in Westmoreland encloses numerous well-defined, dark, round patches, fine-grained and varying in size from ½ to 15 inches in diameter.

In Scotland, the Aberdeen granites (metamorphic, Haughton) contain foliated, subangular inclusions of black mica.

In Ireland, the granite of Newry (metamorphic, Hull; igneous, Kinahan) affords inclusions which are apparently concretions. The Mourne granite (eruptive) contains ovoid and angular, fine-grained dark masses of mica and quartz.

This author derives the following conclusions from these observations:

These granitic inclusions are of two distinct kinds. The first is the result of an abnormal arrangement of the constituent minerals. The second represents the enclosed fragments of other rocks. Of the first, the outline is more or less ovoid, and they are essentially a part of the including granite. The dark color is due to the quantity of mica and hornblende. A second nodule contained in the first, is indicative of concretionary origin.

The formation of rounded inclusions in granites is believed to be contemporaneous with the solidification of the mass, and similar to that of the well known Napoleonite or orbicular diorite of Corsica.

Of the second class, the inclusions are irregular in outline, schistose in structure, traversed by quartz veins or divided by strings of granite. They are frequently unaltered, and are easily recognized as fragments of gneiss, hornblendic and micaceous rocks.

In our own country, Professor Irving, in his report "On the

Copper-Bearing Rocks of Lake Superior" (U. S. Geol. Survey, vol. v, p. 125), refers to a hornblendic granite containing an augitic core, and the entire mass showing minute flakes of biotite. Mr. Clarence King, in his "Systematic Geology" (U. S. Survey, p. 120), graphically describes the remarkable granitic wall of El Capitan, in the Yosemite Valley. This presents a vertical face 3200 feet high, dotted with irregular cloud-like masses and lenticular bodies, apparently segregations of the component minerals (brilliant black hornblende, quartz, biotite and orthoclase). This segregation he considers to be the result of mechanical accidents.

Having thus hastily glanced at observations relating to granitic inclusions in other localities, we are better prepared to understand those of the Craftsbury region. In the following considerations we will observe, first, the including granite itself; second, the included nodules, their external appearance and internal structure, and the relation of the rock-mass to its inclusions.

This nodular granite consists of the usual ingredients of a true granite—quartz, feldspar and mica. The quartz is the most abundant constituent. It possesses the properties of ordinary quartz as to color, lustre and hardness. The feldspar is the common orthoclase, every light in color—even resembling the quartz in this respect. The mica is the black variety (biotite), and is sparingly scattered through the mass. It is in striking contrast with the white components, and gives the rock the appearance of syenite. But no hornblende is present, nor have accessory minerals been observed. These constituents are disseminated irregularly throughout the rock-mass, and since they occur in small dimensions, this mass is fine-grained in texture. According to Prof. H. A. Cutting, State Geologist of Vermont, this granite occurs in place like other granites, but south of the beds it consists of numerous large bowlders.

Professor C. H. Hitchcock refers this granite to the Coös group, which he places directly below the Lower Helderberg division of the Upper Silurian.

The Inclusions.—These are spheroidal or elongated nodules of biotite, from one-half to two inches in diameter, with the long axis sometimes four inches. They are more or less flattened, and frequently consist of only a few plates. Their surface is smooth or sometimes plicated, the folds corresponding to the long axis. Then they resemble a dried butternut, stripped of its epicarp. Several convex scales may be detached from a flat specimen, placed on edge, with a sharp blow of the hammer.

They are distributed irregularly through the rock-mass. In some portions they are more abundant than in others. Some parts of the Craftsbury beds are composed entirely of nodules, slightly cemented by grains of quartz and mica. It appears that there is no law as to their distribution. From this locality to the Canadian line it is stated that these inclusions are very rare, in the beds extending over this area of about forty miles. (C. H. Hitchcock, Geology of Vermont, vol. 2, pp. 564, 721).

The Internal Structure.—But few microscopic sections of these nodules have been prepared. In studying the lithology of New Hampshire, Mr. G. W. Hawes, formerly of the Sheffield Scientific School, made a section of the centre of a nodule, and observed that the biotite is dichroic, that a small portion of muscovite and some quartz are present. No nucleus was apparent, but a concentric arrangement of the mica scales, which he considered to be the basis of the formation of the inclusion. (Geology of New Hamp., vol. 3, pt 4, p. 203.) On account of the limited observations of this peculiar formation, I attempted to prepare some sections of the internal structure. Of these, two were through the centre, and parallel to the longitudinal axis. These show that the biotite is in concentric layers, with grains of quartz scattered irregularly through it. No feldspar is present. These layers of biotite are made up of flakes or long bands. Along the thin edges they are of a light brown color, while the thicker masses are dark. The flakes are of different sizes respecting length and width. They are arranged very much like the scales on a fish. The biotite constitutes the greater part of the surface. It forms fully four-fifths, and doubtless even more in some cases. The quartz is remarkably translucent and very distinctly vitreous. During the grinding process, frequent observations with a lens indicated that the quartz increases in abundance towards the centre.

Several transverse sections parallel to the lateral axis were attempted, but the brittle nature of the biotite prevented success. This, it is thought, may be accomplished by hardening a specimen in shellac dissolved in alcohol. Sections through other portions of the nodule denote the laminated structure of the biotite.

The Relation of the Nodule to the Rock Mass.—The line of contact between the inclusion and the including rock is not always distinct. But it is possible to extract the former with comparative ease. The remaining cavity, however, is usually lined with biotite, which, adhering to it rather than to the nodule, indicates that the inclusion was originally formed from the rock mass. Sections across this line of contact, show considerable quartz and a small quantity of biotite. These minerals are apparently interlocked, further denoting that the biotitic mass belongs to the surrounding rock.

General Conclusions.—First, concerning the nodules: These are not micaceous rolls, for their structure internally shows distinct bands. Nor are they concretions, for no nucleus is observed. But they are masses of flakes of biotite cemented with quartz, abnormally segregated from the original granitic mass. These flakes, although originally concentric, were afterwards arranged radially, hence producing the nodular form. (Dr. Zepharowich, Mineralogical Lexicon, Austria, p. 59.)

Second, concerning the granite: The presence of these nodules indicates the igneous origin of the granite. Were the original mass in aqueous solution, the material would have been evenly distributed, and the nodules could not have occurred. Were it of metamorphic origin, the nodules would scarcely be so uniform in outline and microscopic appearance, but would be more or less contorted. These nodules denote a state of fluidity of the entire mass which resulted from igneous agencies. While in this fluid condition, the nodules first formed, and were enclosed by the surrounding mass. This is sustained by the wrinkled and folded surface of the nodules, which doubtless was occasioned by the contraction of the surrounding mass as it cooled.

The fact that biotite is a frequent constituent of igneous rocks, has its influence in sustaining the igneous origin of this granite. This is also sustained by the investigations of local phenomena. (Geology New Hamp., vol. 1, p. 538.)

The inclusions at Craftsbury are unique in type, differing from those of all other localities.

These observations may be modified by further investigations, but it is hoped that they may elicit an extended interest in the subject.

Appendix.—Since the preceding pages were written, my attention was directed to inclusions in certain flaggings in Philadelphia, on Chestnut Street above Third Street, and on Filbert Street above Thirteenth Street. It was desirable to trace the localities of these rocks.

By the assistance of the City Commissioner of Highways, and the dealer who furnished the stone for the Chestnut Street pavement, the locality was ascertained to be Connecticut or Maine.

The doubt in the case arises from the fact that the stone was furnished about twenty-five years ago, no record of its locality was kept, and the dealer is unable to recall with any degree of certainty the exact location. The granite in external characters closely resembles that of New London, Conn., as well as that of Sullivan, Maine. Hence this feature is comparatively valueless in the determination. But the resemblance of the inclusions to those in the Sullivan granite, favors the view that this location is the home of the Chestnut Street flags.

These inclusions are not numerous, nor regular in size and outline. They are made up of biotite, are elongated elliptically, frequently terminating in acute points. The length is eight or ten inches, and the width two or three inches. These masses blend into the surrounding rock, without affording any distinct line of separation, hence suggesting that their extraction would involve considerable difficulty. That these were produced in a way similar to those of Craftsbury, is apparent from external observations, and doubtless sections of the internal structure will sustain this supposition.

No evidence was obtained concerning the locality of the Filbert Street rock. Its worn condition denotes a long period of service. These inclusions tend to detract from the value of granites, as they afford an easy access for destructive agents (moisture, frost, heat), and hence such granites having a limited use, are not apt to be seen along public thoroughfares.